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Preliminary Observations on the Mechanical Extraction of Meats from the Sea and Iceland Scallop

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PRELIMINARY OBSERVATIONS ON THE MECHANICAL EXTRACTION OF MEATS FROM THE SEA AND ICELAND SCALLOP

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ABSTRACT

Naidu, K. S. 1989. Preliminary observations on the mechanical extraction of meats from the sea and Iceland scallop. Can. MS Rep. Fish. Aquat. Sci. 2023: v + 10 p.

Sea scallops (Placopecten magellanicus) and Iceland scallops (Chlamys islandica) were subjected separately to a prototype mechanical shucking device used normally for calico scallops (Argopecten gibbus). Gaping was effected with pressurized steam and separation of viscera from shells was induced mechanically on a perforated vibrator plate. While gaping and ejection were readily achieved, individual viscera did not always become separated from the shell stock because of the small apertures on the vibrator plate. Differences in average individual meat yields between biological (hand-shucked) and mechanically extracted scallops were significant for both species. Most of the loss was incurred during the process of evisceration where the adductor muscle (meat) is separated from the viscera. Estimate of loss in individual meat yields for sea scallops in the 76-100 mm size (SH) range was approximately 18% but, for scallops greater than 101 mm this decreased to about 10%. For commercial-sized (66-90 mm) Iceland scallops the loss was estimated to be about 15%. A weight loss of only 4.3% was recorded for the much smaller calico scallop.

It is concluded that removal of some of the physical constraints, together with some secondary processing, may well result in the deployment of the shucking machine for Iceland scallops. The mechanical device ought to extract meats more rapidly and cheaply than through labor intensive and tedious manual shucking.

RÉSUMÉ

Naidu, K. S. 1989. Preliminary observations on the mechanical extraction of meats from the sea and Iceland scallop. Can. MS Rep. Fish. Aquat. Sci. 2023: v + 10 p.

On a essayé séparément sur des pétoncles géants (Placopecten magellanicus) et sur des pétoncles d'Islande (Chlamys islandica) un prototype de décoquilleur mécanique utilisé normalement sur des peignes calicots (Argopecten gibbus). L'ouverture de la coquille s'effectuait à l'aide de vapeur sous pression et l'éviscération était réalisée mécaniquement au moyen d'une lame vibrante perforée. L'ouverture et l'expulsion n'ont pas posé de difficulté, mais l'éviscération était parfois incomplète, à cause des petites ouvertures ménagées sur la lame. La différence de rendement moyen entre le décoquillage manuel et le décoquillage mécanique s'est avérée importante dans le cas des deux espèces. Les pertes se sont produites pour la plupart durant l'éviscération, c'est-à-dire durant la phase de séparation du muscle adducteur (noix ou chair) et des viscères. En ce qui concerne les pétoncles géants, la perte approximative était de 18 p. 100 parmi ceux dont la taille variait de

76 à 100 mm (hauteur de coquille) mais diminuait à environ 10 p. 100 parmi les spécimens dont la taille était supérieure à 101 mm. Dans le cas des pétoncles d'Islande de taille commerciale (de 66 à 90 mm), elle était d'environ 15 p. 100. Dans les peignes calicots, de plus petite taille, cette perte n'est que de 4,3 p. 100.

On peut déduire de l'expérience que la suppression de certains des obstacles physiques ainsi qu'une certaine part de transformation secondaire pourrait aboutir à l'utilisation de la décoquilleuse sur les pétoncles d'Islande. Ce dispositif permettrait une extraction des chairs plus rapide et plus économique que le décoquillage manuel, méthode fastidieuse et à fort coefficient de main-d'oeuvre.

INTRODUCTION

Of the two scallop species found in Newfoundland (Fig. 1), only the sea scallop, Placopecten magellanicus, is presently fully exploited. The smaller Iceland scallop, Chlamys islandica, frequently is discarded particularly by the Maritimes-based offshore fleet prosecuting a mixed-species fishery on St. Pierre Bank, a westward extension of the Grand Banks of Newfoundland (Naidu and Cahill 1984). The tight shell closure of freshly-caught Iceland scallops makes them relatively more difficult to shuck than the sea scallop. Like oysters (Whyte and Carswell 1984), hand shucking of this species is relatively more difficult, tedious and somewhat hazardous from shell lacerations. To date, attempts to develop a directed fishery based exclusively on the Iceland scallop by vessels smaller than 20 m (65 ft) have been thwarted principally by limitations imposed by shucking capacity which frequently become limiting. This, coupled with significant losses to industry through manual shucking (Naidu 1987), has encouraged industry to examine other options, including automatic or mechanical shucking devices.

Various methods have been investigated over the years to mechanically extract scallop meats from shells (Harris 1958; Carpenter 1960; Bullis and Love 1961; Polito 1964; Renfroe 1964; Matzer 1965; Wenstrom and Gorton 1966; Williams 1966; Marvin and Henderson 1966; Brown 1967; Meyer 1969; Anon. 1970; Nelson 1970; Willis 1971; Chleborowicz 1972; Olafsson 1972). While the technologies are similar, the most effective method is contained in a U.S. Patent filed by Willis Bron, Inc., Willingston, North Carolina, U.S. Patent 3,562,855 (Attorneys: Finnegan, Henderson and Farabow). The equipment was originally designed for the processing of calico scallops (Fig. 1). However, information on yields resulting from mechanical shucking devices, even for a species for which it is routinely used, such as the calico scallop, Argopecten gibbus, is limited (Otwell et al. 1984) or not readily available. This preliminary study was conducted to determine the efficiency of meat recovery of a prototype shucking machine normally employed for extracting meats from the calico scallop and evaluates its potential for the processing of sea and Iceland scallops, principally with a view to utilizing the device to accelerate the development of a directed fishery for the underutilized species (Iceland scallops) on St. Pierre Bank and the Grand Banks of Newfoundland. Sea scallops were examined here incidentally and as a comparison only. It is unlikely that mechanical shucking will replace the hand shucking customarily employed for this species.

MATERIALS AND METHODS

The equipment used in this study was originally designed for processing calico scallops. Since patent and ownership rights of the prototype shucking machine used in this study are in litigation in New York, N.Y, we were allowed access to and use of equipment on the condition that detailed specifications were not reported or elaborated upon. The author is obliged to abide by this request for confidentiality and, consequently, unable to describe in detail the equipment or the process. Suffice to say that scallops in the shell were subjected to pressurized steam at approximately 80-100°C. This resulted in the ejection of the visceral mass, including the adductor muscle (meat), from the valves which become instant cluckers (scallop shells still attached at the hinge line). The soft parts comprising of the mantle, gonad and adductor muscle fall through perforations on a vibrator plate. Finally, the meats become separated on an "eviscerator" consisting of a series of oscillating rollers, similar to those utilized in shrimp peeling machines. Additional information on the technical aspects of the machine may be found in U.S. Patent No. 3,562,855 of February 16, 1971.

All established firms in Florida and Georgia use the same basic processing methodology with slight modifications and innovations to suit specific requirements (Otwell et al. 1984). Attempts to place processing facilities onboard vessels customarily used in the calico scallop fishery (15-80 m) have proven to be either impractical or not cost-effective compared with land-based operations (Otwell et al. 1984).

Sea and Iceland scallops were procured from St. Pierre Bank from May 5-11, 1987. Specimens were collected from a wide area of the Bank from depths ranging from 45 to 70 m where bottom temperatures varied narrowly between 1.2 and 1.6°C. Each species was collected by size and separated into two comparable size frequencies. An attempt was made to procure specimens to represent the full size range for each species. The four lots were separately kept in running sea water while at sea. Upon arrival (May 12, 1987) in port (St. John's, Newfoundland) scallops were transferred into salt-water aquaria at the Northwest Atlantic Fisheries Center. On May 14, 1987 two of the batches each consisting of 493 sea and 482 Iceland scallops were packed in heavy wax cartons without free water and air freighted to Jacksonville, Florida. Upon arrival (approximately 24 hrs) scallops were trucked to Darian, Georgia (2 hrs). While the scallops were dead upon arrival, they were still quite fresh (acceptable odor, white translucent meats).

Temperature of contents within the wax cartons upon arrival in Georgia was 17°C (63°F) while air temperature was 30°C (86°F). The two species were assembled separately into size groups and mechanically shucked without any modifications to the equipment. Ten batches of Iceland scallops grouped by 5 mm intervals and three batches of sea scallops each consisting of animals less than 75 mm, greater than 100 mm, and those in between were separately processed. Iceland scallops measuring less than 55 mm (N = 84) were processed as one batch. Numbers of meats extracted and their individual weights to the nearest 0.1 g were determined.

In the meantime, the two remaining batches of sea (N = 584) and Iceland scallops (N = 526) back in the laboratory were individually hand shucked to completely extract meats. Size-specific meat weights were assembled, again to the nearest 0.1 g. Average yield (g, meat) by size category from the biologically-dissected and mechanically-extracted meats was compared for the two scallop species. As it was impossible to determine the size specificity of individual meats from mechanical shucking where scallops were bulk processed, comparisons between the differences in meat yield from the two methods of extraction are

limited to size groups rather than to individual scallops as in Naidu (1987).

Preliminary observations on the efficiency of mechanical extraction of calico scallops are based on an opportunistic visit to a scallop processing plant where calico scallops were being processed. A random sample of yet-to-be-processed scallops consisting of 60 animals were hand-shucked and individual meat weights determined. The mean weight from the biologically-dissected scallops was compared with the mean weight of a random sample of 156 meats from the assembly line that had been mechanically extracted from the same catch.

Thickness of valves in the area where the adductor muscle is attached to the shell (muscle scar) was estimated with a micrometer screw gauge. These were done separately for calico scallops and two size groups of Iceland scallops each measuring $\leq$55 mm and $\geq$66 mm. Sea scallops were not investigated in this regard.

RESULTS

CALICO SCALLOPS (ARGOPECTEN GIBBUS)

It is assumed that the shell-height distributions for each of the two treatments for calico scallops were similar. Shell height was unimodal (Fig. 2) and ranged narrowly between 41 and 54 mm ($\bar{x}$ = 46.4 $\pm$ 2.7 mm). Thickness of valve (shell material) in the area of the muscle scar was estimated to be 2.37 $\pm$ 0.24 mm (N = 50). While the difference in yield between biologically-dissected and mechanically-shucked meats (Table 1) was statistically significant at the 5% level, a loss of 4.3% is considered acceptable by industry standards.

Some additional hand-cleaning of scallop meats was necessary to remove extraneous attachments. Sometimes meats were picked off the assembly line and returned to the eviscerator for further cleaning. On the whole it appeared that meats were efficiently shucked for this species.

SEA SCALLOPS (PLACOPECTEN MAGELLANICUS)

Generally, the equipment appeared to work well for extracting sea scallop meats. Although thermal treatment resulted in gaping and ejection of the viscera, the perforations on the vibrator plate (screen) were not large enough to allow individual viscera to fall through. Instead, the detached soft parts came through in the wash together with shells. These were manually removed and placed on the eviscerator. Approximately 72% of scallops used in the trials were shucked albeit some with manual assistance. Biologically-dissected and mechanically-shucked yields for the three size groups examined are summarized in Tables 2 and 3. Differences in the average meat yield/scallop between the two are summarizied in Table 4. Differences for the size group less than 75 mm were statistically significiant ($P \leq 0.05$) and highly significant for the 76-100 mm and $\geq$101 mm size groups ($P \leq 0.1$).

Overall a 9% increase in meat weight was evident. This is ascribed to incomplete removal of the gonadal tissue and digestive gland which remained attached to the meats and perhaps to an enhanced moisture binding capacity associated with partially denatured meats. Approximately 10% of mechanically extracted meats had sizeable portions of undesirable tissue still attached. Meats from the smallest size group ($\leq$75 mm) were least efficiently separated from the viscera and needed most of the secondary processing. There was also a problem within the rollers of the eviscerator which resulted in the undue tearing of some meats. Larger meats tended to remain on the oscillating rollers longer than necessary. Increasing the transport gradient may have satisfactorily resolved this problem.

ICELAND SCALLOPS (CHLAMYS ISLANDICA)

Valve thickness in the area where scallop meats were attached to the shell for Iceland scallops $\leq$55 mm (39.3 $\pm$ 2.4 mm) and $\geq$66 mm (83.8 $\pm$ 8.8 mm) were 0.73 $\pm$ 0.10 mm (N = 50) and 1.67 $\pm$ 0.41 mm (N = 50), respectively. Not correcting for radial ribbing these were found to be significantly thinner than those of the calico scallop ($P \leq 0.05$).

Biologically-dissected and mechanically-shucked meat yields by 5 mm size classes are shown in Tables 5 and 6. Differences in size-specific yields between the two treatments are summarized in Table 7. Again, with the exception of scallops smaller than 60 mm there were losses in meat yield for each 5 mm group examined. Overall the differences in sample means were not significant ($P \geq 0.05$) for the smaller size groups ($\leq$55 mm) but highly significant ($P \leq 0.01$) for scallops in the 65-90 mm size range. At best only 36% of scallop meats were extracted through the heat and mechanical evisceration process. There was frequent and often unquantifiable manual intervention, particularly in removing the visceral mass from within the scallop. Further losses were evident when soft body parts were placed on the eviscerator for separating adductor muscles from the visceral mass. There was a tendency for the rollers to "pinch" and tear off peripheral connective tissue often resulting in tearing off and loss of portions of adductor muscles. On a number of occasions meats considered "dirty" were manually replaced on the eviscerator for further cleaning. Still more losses were incurred each time the meats were gravity-fed to remove extraneous tissue from the adductor muscle. Sometimes the eviscerator reduced meats to small bits and pieces which were subsequently lost in the wash. Total weight of fragments that were retained is separately reported in Table 5. Tenacity of adherence of unwanted soft tissues (gonad, digestive gland, etc.) was most prevalent in this species. As a result, in spite of added weight components from undesirable fractions, there was a 15% net loss in the mean adductor muscle weight for commercially-sized scallops whose meats were mechanically extracted. It is probably premature to compare this with an average loss of 23% reported for the species manually shucked at sea (Naidu 1987).

CONCLUSIONS

With only a 4.3% loss in yield between biologically-dissected and mechanically-shucked calico scallops, the shucking machine must be rated as very efficient for that species. A

weight loss of 6.5% reported by Otwell et al. (1984) was partially ascribed to moisture loss during processing but they were not able to reconcile their conclusion with water uptake by raw scallop meats soaked in water and salt solutions reported by Thomas and Porter (1978). Without this equipment it is unlikely that the small species, seldom exceeding 60 mm, could be harvested commercially to the extent it is today. There were additional losses in the process of mechanical shucking. Scallops not opened by the heat treatment, those not detaching from the shell or not falling through the perforated shakers were passed on and discarded along with empty shells. The author saw no attempt to recover these. Such losses, while important, could not properly be addressed in this study but were variously estimated to run as high as 5 to 20%. Remuneration to fishermen is based not on gross landed weight but on the quantity of meats produced (yield) from a given catch. These losses do not appear to be a concern to the processor.

Of the three species tested, Iceland scallops seemed to pose the most problems but prospects for their resolution are encouraging. For sea scallops the constraints appear to be associated with using a device not adjusted for accommodating much larger species than the calico scallop. Considering that the shells (valves) of the Iceland scallop were significantly thinner than those of the calico, it is probable that the heat shock customarily used for calico scallops was somewhat excessive for Iceland scallops and resulted in various degrees of thermal denaturation. Problems were again encountered both at the vibrator/shaker where apertures were clearly too small to allow individual soft parts to fall through. Neither the size of the oscillating rollers nor the spacings between them had been adjusted for handling the larger species. This resulted in undue pinching and tearing of adductor muscle tissue. The apparent higher meat yield from mechanically-extracted Iceland scallops smaller than 55 mm and sea scallops less than 75 mm, while not statistically significant, may be ascribed primarily to undesirable attached fractions (gonad, digestive gland, etc.) and perhaps to enhanced moisture-binding properties of partially-cooked (surface-denatured) meats (Fennema 1977). Physical losses during the mechanical extraction process, however, offset these gains in the larger Iceland ($\geq$66 mm) and sea ($\geq$71 mm) scallops resulting in overall losses in average meat yield (g, meat) in both species.

Removal of these physical constraints, together with some secondary processing at the final stages to remove extraneous tissue from meats, may well result in the use of the shucking device for the larger species. In this regard it should be pointed out that initially processors both in Iceland and more recently in Norway only had limited success with the device for handling Iceland scallops (cited by Venvik and Vahl 1979). Changes and modifications to the original equipment have resulted in it now being routinely used for Iceland scallops both in Iceland and in Norway and for queen scallops (Chlamys opercularis) in Scotland. Currently, a number of these machines are in use in the United States, Norway, and Peru. A success rate of 95% has been reported for Iceland scallops (cited by Venik and Vahl 1979). Studies in Norway (Venvik and Vahl 1979) have shown that scallop condition prior to mechanical shucking is critical to its success. Soaking whole scallops overnight in fresh water, as is sometimes done with calico scallops, was found to result in easier release of soft parts when shock heated. The observations reported in this paper for Iceland scallops are based on a single sample only, consisting of 482 animals. Further trial runs to improve yield would seem appropriate before routine commercial application.

The initial thermal shock should result in complete gaping and ejection of soft parts (viscera) without undue cooking of meat. In the trial runs used in this study, some heat denaturing of meats was obvious. The peripheral gloss evident on fresh hand-shucked meats had disappeared during the heat treatment. This was particularly evident in smaller scallops and may be met with some consumer resistance if the product is to be marketed as 'fresh' scallops. The transition from native to denatured state occurs within a narrow range of temperature (Kinsella 1984). Precise definition of this temperature would be critical to the success of the method for Iceland scallops as would the ability to adjust this temperature when epibionts are prevalent. The degree of shell encrustation from barnacles on the shells of calico scallops, for example, can insulate the meats thus requiring more heat to effect proper gaping and ejection of viscera (Otwell et al. 1984). Asymmetric heat transfer may also be a problem. While soaking shell stock overnight may have obvious advantages to thermal gaping and ejectability using less heat (Kinsella 1984) meat quality and shelf life may be impaired. A compromise must be found within the context of the intended use of the finished product. For example, more cooking may be tolerated if the end product is destined for the fast-food market where scallops are to be battered and deep fried. This study did not attempt to examine differences in meat quality (if any) between hand-shucked (native state) and mechanically-extracted meats where partial thermal denaturation was evident. Organoleptic attributed (odor, texture, appearance, flavor) and overall acceptability of scallop meat obtained for mechanical shucking treatment needs appropriate attention.

In the author's opinion, the mechanical shucking device ought to extract meats more rapidly and cheaply than manual shucking. Processing technology must not only recover scallops not successfully shucked the first time but bits of meats lost in the wash during evisceration. Avoidance of thermal denaturation is a problem that needs resolution. Practical problems would include separating scallops into uniform size categories and determining time/temperature effects within the processing regime. Adjustments to processing equipment will be unlikely if scallops used and resulting end products (meats) have uniform physical characteristics. Calico scallops are limited in their size distributions and appears to pose few problems in this regard.

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Table 1. Difference in meat yield (g ± 1 S.D.) between biologically-dissected and mechanically-shucked calico scallops.

Size class (mm)	Average meat yield/scallop		Percent change
	Biological (N)	Mechanically-shucked (N)	
42-54	2.3 ± 0.5 (60)	2.2 ± 0.3 (156)	-4.3

Table 2. Size-specific meat weights (± 1 S.D.) of sea scallops obtained through mechanical shucking and weights of bits and pieces recovered at the end of the processing line.

Size class (mm)	No. used	No. meats extracted	Mean adductor muscle weight (g) ± 1 S.D.	Weights (g) and (numbers) of bits & pieces
<75	170	66	4.7 ± 1.9	45.1 (2)
76-100	169	151	9.4 ± 2.4	56.7 (15)
>101	154	138	28.3 ± 5.7	222.8 (20)
Totals	493	355	15.9 ± 10.8	324.6 (37)

Table 3. Size-specific meat weights (± 1 S.D.) of sea scallops obtained from biological dissections.

Size class (mm)	No. used	Mean adductor muscle weight (g) ± 1 S.D.
<75	222	4.1 ± 1.8
76-100	190	11.5 ± 2.5
>101	172	31.5 ± 6.2
Totals	584	14.6 ± 12.0

Table 4. Size-specific differences in meat weight (g) between biologically-dissected and mechanically-shucked meats in sea scallops.

Size class (mm)	Average meat yield/scallop		Percent change
	Biological (N)	Mechanically-shucked (N)	
<75	4.1 (222)	4.7 (66)	+14.6
76-100	11.5 (190)	9.4 (151)	-18.3
>101	31.5 (172)	28.3 (138)	-10.2
Totals	14.6 (584)	15.9 (355)	+8.9

Table 5. Size-specific meat weights (± 1 S.D.) of Iceland scallops obtained through mechanical shucking and weights of bits and pieces recovered at the end of the processing line.

Size class (mm)	No. used	No. meats extracted	Mean adductor muscle weight (g) ± 1 S.D.	Weights (g) and (numbers) of bits & pieces
<55	74	12	3.6 ± 1.5	12.1 (6)
56-60	43	13	4.8 ± 1.5	24.9 (9)
61-65	49	1	4.5	- (1)
66-70	62	23	5.5 ± 1.0	66.5 (18)
71-75	65	32	6.4 ± 1.6	27.3 (8)
76-80	80	37	7.5 ± 1.6	62.2 (17)
81-85	65	30	10.0 ± 2.4	44.0 (31)
86-90	32	25	10.6 ± 3.1	29.8 (26)
91-95	12	1	10.0	2.5 (1)
Totals	482	174		

Table 6. Size-specific meat weights (± 1 S.D.) of Iceland scallops obtained from biological dissections.

Size class (mm)	No. used	Mean adductor muscle weight (g) ± 1 S.D.
0-45	9	2.0 ± 0.9
46-50	19	2.6 ± 0.4
51-55	50	3.3 ± 0.6
56-60	46	3.8 ± 0.7
61-65	59	5.2 ± 1.0
66-70	68	6.2 ± 1.4
71-75	72	8.1 ± 1.4
76-80	77	8.9 ± 2.3
81-85	59	12.0 ± 2.4
86-90	38	12.8 ± 2.8
91-95	19	16.7 ± 2.7
96-100	10	15.5 ± 2.8
Total	526	

Table 7. Size-specific differences in meat weight (g) between biologically-dissected and mechanically-shucked Iceland scallops.

	Average meat yield/scallop		
Size class (mm)	Biological (N)	Mechanically shucked (N)	Percent change
0-45	2.0 (9)		
46-50	2.6 (19)	3.6	+20.0
51-55	3.3 (50)		
56-60	3.8 (46)	4.8 (13)	+26.3
61-65	5.2 (59)	4.5 (1)	-13.5
66-70	6.2 (68)	5.5 (23)	-11.3
71-75	8.1 (72)	6.4 (32)	-21.0
76-80	8.9 (77)	7.5 (37)	-15.7
81-85	12.0 (59)	10.0 (30)	-16.7
86-90	12.8 (38)	10.6 (25)	-17.2
91-95	16.7 (19)	10.0 (1)	-40.1
96-100	15.5 (10)	-	

Table 8. Size-specific differences in meat yield (g ± 1 S.D.) between biologically-dissected and mechanically-shucked commercial-size Iceland scallops.

Size class (mm)	Average meat yield/scallop		Percent change
	Biological (N)	Mechanically shucked (N)	
<55	3.0 ± 0.8 (84)	3.6 ± 1.5 (12)	+20.0
66-90	9.4 ± 3.1 (313)	8.0 ± 2.8 (148)	-14.9

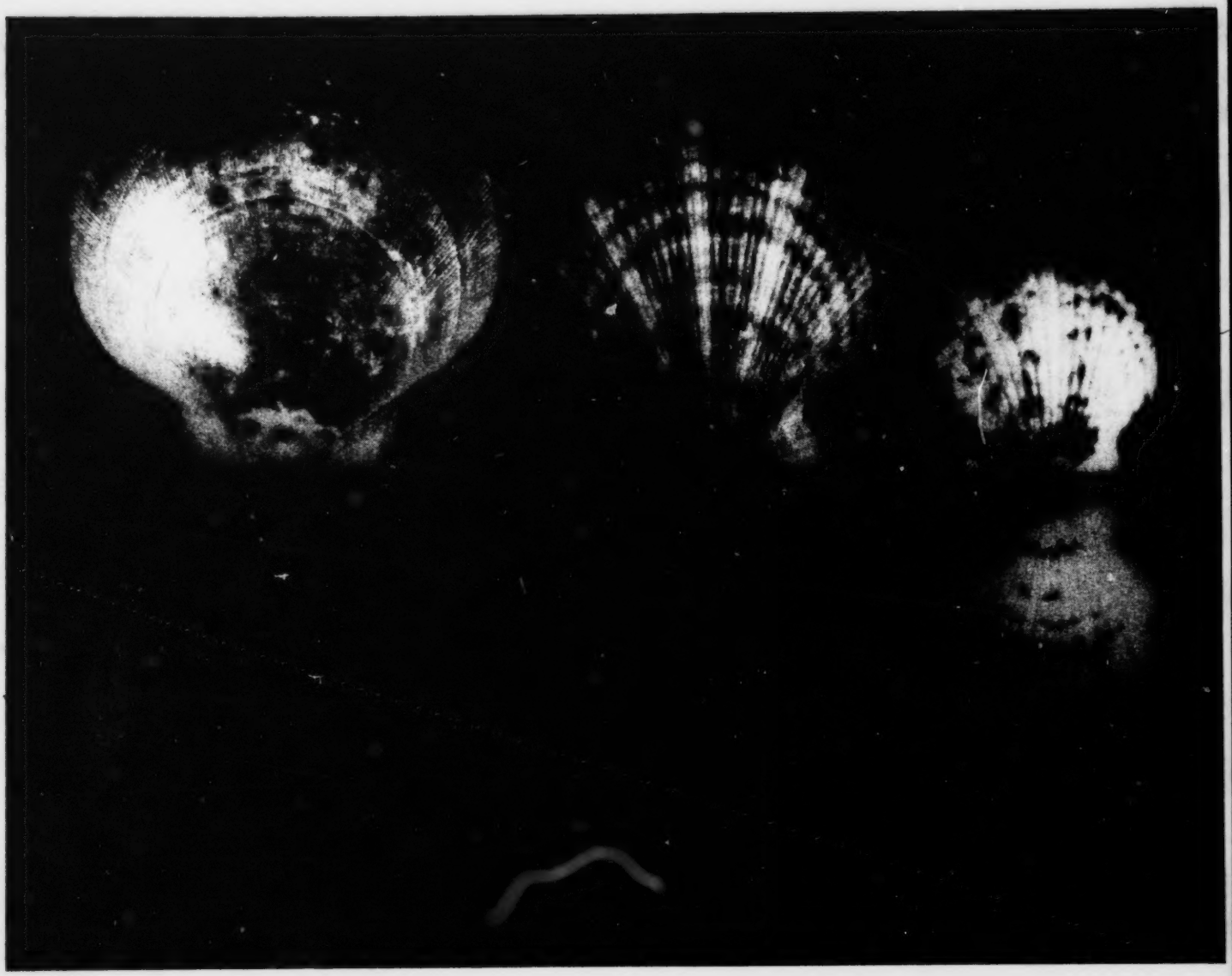

Fig. 1. Left to right: sea (95.3 mm), Iceland (74.0 mm), and Calico (47.3 mm) scallop.

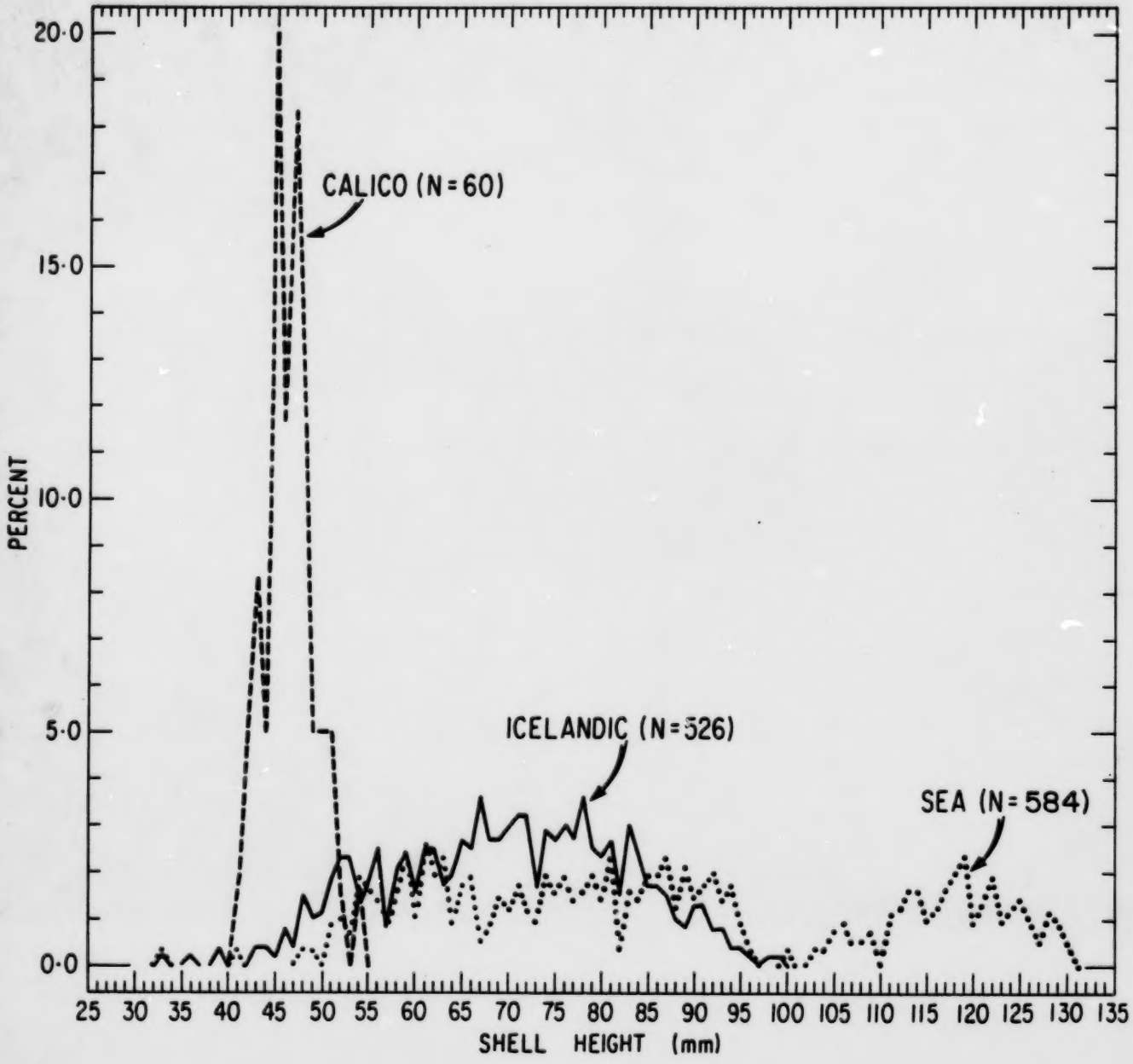

Fig. 2. Shell height distributions of Calico, Iceland and sea scallops used in the study.